



Escola Politècnica Superior
d'Enginyeria de Vilanova i la Geltrú

UNIVERSITAT POLITÈCNICA DE CATALUNYA

EPS - PROJECT

TITLE: Intelligent Transport Systems

STUDENTS: Andrew Pavek, Duygu Akin, Kristina Engström,
Nils Dageförde, Pedro Cardenas, Sindy Glawion

SUPERVISORS: Àngels Hernández

TITLE: Intelligent transport systems

FAMILY NAME: Pavek

FIRST NAME: Andrew

HOME UNIVERSITY: South Dakota School of Mines and Technology

SPECIALITY: Electric engineering

FAMILY NAME: Akın

FIRST NAME: Duygu

HOME UNIVERSITY: Dumlupınar University, Kütahya Turkey

SPECIALITY: Ceramic engineering

FAMILY NAME: Engström

FIRST NAME: Kristina

HOME UNIVERSITY: Royal Institute of Technology, Stockholm Sweden

SPECIALITY: Design and product development

FAMILY NAME: Dageförde

FIRST NAME: Nils

HOME UNIVERSITY: University of applied science, Kiel Germany

SPECIALITY: Business engineering

FAMILY NAME: Cardenas

FIRST NAME: Pedro

HOME UNIVERSITY: UPC Escola Politècnica Superior d'Enginyeria de Vilanova i la Geltrú

SPECIALITY: Electronic engineering

FAMILY NAME: Glawion

FIRST NAME: Sindy

HOME UNIVERSITY: Freiberg University of Mining

SPECIALITY: Marketing, development and project management

Abstract

This report contains information about Intelligent Transport Systems and testing scenarios on IDIADA's proving ground. Since the automotive industry is rapidly moving in the direction of advanced active safety, Intelligent Transport System (ITS) and Advanced Driver Assistance Systems (ADAS) are two the keys for enabling the European Road Safety Project to reach the goal of 50% less car crashes per year by 2010.

Therefore, the following systems have been researched:

ITS – Communication between On Board Units (OBU) and Road Side Units (RSU)

ADAS – Detecting Obstacles (Pedestrian and Car)

HMI – Human Machine Interface (Interaction between the driver and ITS/ADAS)

With the results of this research, testing methods and protocols have been developed in all three of these systems according to ISO standards. Finally, a comprehensive offer about testing services on IDIADA's proving ground is explained.

Key words: Intelligent Transport System, Advanced Driver Assistance System, Human Machine Interface, ISO standards

Table of Contents

1. Introduction	4
1.1 Main aims of the project	4
1.2 Project structure.....	4
2. Glossary.....	5
3. ADAS – state of the art	6
3.1 ACC(Adaptive Cruise Control).....	6
3.2 FCW(Forward Collision Warning)	8
3.3 Pedestrian detection systems	9
4. ITS (Intelligent Transport System) – state of the art.....	11
4.1 ITS Protocols.....	12
4.2 ITS Projects.....	13
4.3 Analysis on vehicle-to-infrastructure	13
5. HMI (Human Machine Interface) – state of the art.....	14
5.1 HMI Devices Using In Vehicles.....	14
5.2 Subjective HMI protocol	16
6. Scenario research	18
6.1 Common traffic environments	18
6.2 Special circumstances.....	20
7. IDIADA’s proving ground	23
7.1 Testing tracks.....	23
7.2 Lab equipment	24
8. Testing scenarios.....	27
9. Possible applications.....	29
10. ITS/ADAS data base	30
11. ITS and ADAS service business	32
11.1 Target group.....	32
11.2 Context.....	32
11.3 Handbook.....	32
11.4 Presentation	33
12. Conclusion	34
13. Recommendations	35
14. Bibliography	36

1. Introduction

The automotive industry is moving rapidly in the direction of advanced active safety. Intelligent Transport System (ITS) and Advanced Driver Assistance Systems (ADAS) are the key for enabling the next generation of safety applications to help prevent almost 50% of today's crashes by 2010; the goal of the European Road Safety action Program [1]. Due to the increased amount of vehicles on the roads such systems are needed to provide safe and stress free driving.

The main purpose of ADAS and ITS systems is to improve the safety on our roads by informing the driver about current traffic situations. The aim of ADAS is to detect other cars and pedestrians in the surrounding area. ITS on the other hand is communication between On Board Units (OBU), which are mounted on the car and Road Side Units (RSU), which reside permanently along the roadside. The gained information provided by the telecommunication systems are transmitted to the driver in a proper way supported by the Human Machine Interface (HMI). This interface deals with how the information should be displayed to the driver in both non critical and critical situations without causing confusion to the driver.

1.1 Main aims of the project

The main goal of the project is to through research on transport communication technologies, develop methods to test ITS and ADAS on IDIADA's proving ground. Therefore, comprehensive research on possible applications for the new technologies is to be done as a foundation for the project.

The tests are to follow current ISO standards and are to be developed both subjectively and objectively. Subjectively means the individual perception of persons is being considered, whereas objectively assumes to be independent on any circumstances and without taking personal perceptions into account. To decrease driver failure evaluation protocol for HMI is developed as well. The new testing methods are to be offered to the clients of IDIADA in an appropriate and sufficient manner.

1.2 Project structure

The project is divided in to two stages where stage one is six individual tasks and stage two is more collaborative. For the first task a state of the art of ITS, ADAS and HMI where written after thoroughly research was conducted. This research was done as a background studies for the development of the evaluation protocols in task two. Due to the fact that the evaluation protocols and testing methods developed have to follow relevant ISO standards, a data base for ITS and ADAS standards where created. Because of that in the second part testing methods have been developed, testing scenarios where stated and described.

The second part of this project was to develop testing methods for ITS and ADAS, objective and subjective evaluation protocols for the tests and a subjective evaluation protocol for HMI. There was also a presentation and handbook created with the aim to send IDIADA's services to clients.

2. Glossary

ACC	Adaptive Cruise Control: Adjusting individual velocity to Traffic by detecting cars in front.
ADAS	Advanced Driver Assistance Systems: Can detect cars, Pedestrians and other obstacles.
ATM	ATM is a computerized telecommunications device that provides the customers of a financial institution with access to financial transaction in a public space without The need for a human.
C2C	See V2V
C2I	See V2I
CTS	Clear to Send Message
DSRC	Dedicated Short Range Communication
FCW	Forward Collision Warning
FPD	Flat Panel Display
GPS	Global Positioning System
HMI	Human-Machine-Interface: Interface between humans And the assistance systems
IEEE	nstitute of Electronical and Electronics Engineers
ISO	International Standardisation Organisation
ITS	Intelligent Transport System: Enables communication Between vehicles.
LCD	Liquid Crystal Display
OBU	On Board Unit: A data sending and receiving device for Intelligent Transport System installed in vehicles. Thus, it is mobile.
POV	Principle Other Vehicle
RSU	Road Side Unit: It is a data sending and receiving device for Intelligent Transport System permanently mounted Along the road side.
SV	Subject Vehicle
TFT	Thin Film Transistor: Display
TTC	Time to Collision
V2I	Vehicle to Infrastructure: Way of communication within Intelligent Transport System.
V2V	Vehicle to Vehicle: Way of communication within Intelligent Transport System.
VANET	Vehicular Ad-Hoc Networks
WAVE	Wireless Access for Vehicular Environment

3. ADAS – state of the art

Since the late 80's/early 90's technology such as ABS (Anti-lock Braking System) and Air bags were developed to improve transportation safety. Air bags are a form of *Passive safety systems* and ABS is an *Active safety system*. ADAS (Advance Driver Assistance System) was developed in the mid to late 90's with ACC (Adaptive Cruise Control), which is a form of active safety. From this point on, many other systems have been developed within ADAS, which includes: Drowsiness Detection, Lane Departure Detection, Forward Warning Collision, Blind Spot and many other driving assistance systems. [2] [3] The main goal and push behind all of these systems is to not only increase the safety of the driver, but also to create a more relaxed, stress-free driving experience.

3.1 ACC(Adaptive Cruise Control)

ACC is a system that contains an on board radar, lidar or camera sensor to determine azimuth, speed, altitude, and other useful information of up coming vehicles. [4] From this data the system is able to accelerate or brake the vehicle according to a customizable distance that is to be maintained from other vehicles. There are two ACC systems within ACC, one which is the standard ACC and the other is ACC Stop and Go. The only difference between the two is that ACC Stop and Go is capable of going from one speed all the way to a complete stop and resuming to the original speed, without human intervention. [2]

When developing an ACC system there are six things to consider: vehicle speed, vehicle lateral acceleration, driver accelerator input, driver steering input, driver brake input and the data from some type of sensor. [5] This being said, there is a lot to take into account and many different ways to complete this task. But one thing that needs to be consistent is the testing method in which this system will be approved to be implemented into vehicles. Therefore, an ACC Stop and Go protocol was developed for this project, that included testing for five general scenarios where ACC Stop and Go is most commonly used. This protocol could also be used for ACC systems as long as the 'Stopping Test' is not including. Within these five scenario tests, there are different testing speeds and two different weather conditions including wet and dry (refer to table 1 for a scenario matrix for the different protocol coverage). The protocol does not cover icy or heavy rain road conditions, this is because it is highly not recommended to have any form of cruise control while driving on bad road conditions.

Scenario		Road Conditions	Road Type	Driving Environment
2.1.1	Subject Vehicle Encounters Slower Principle Other Vehicle	Dry	Main Road	Traffic Jam
2.1.2				Free Flowing Traffic
2.1.3			Highway	High Speed(120kph)
2.1.4				High Speed(200kph)
2.2.1		Wet	Main Road	Traffic Jam
2.2.2				Free Flowing Traffic
2.2.3			Highway	High Speed(120kph)
2.2.4				High Speed(200kph)
3.1.1	Subject Vehicle Follows Principle Other Vehicle and the POV Switches Lanes	Dry	Main Road	Traffic Jam
3.1.2				Free Flowing Traffic
3.1.3			Highway	High Speed(120kph)
3.1.4				High Speed(200kph)
3.2.1		Wet	Main Road	Traffic Jam
3.2.2				Free Flowing Traffic
3.2.3			Highway	High Speed(120kph)
3.2.4				High Speed(200kph)
4.1.1	Subject Vehicle Follows Principle Other Vehicle and the POV Brakes	Dry	Main Road	Traffic Jam
4.1.2				Free Flowing Traffic
4.1.3			Highway	High Speed(120kph)
4.1.4				High Speed(200kph)
4.2.1		Wet	Main Road	Traffic Jam
4.2.2				Free Flowing Traffic
4.2.3			Highway	High Speed(120kph)
4.2.4				High Speed(200kph)
5.1.1	Subject Vehicle Follows Principle Other Vehicle and the POV Accelerates	Dry	Main Road	Traffic Jam
5.1.2				Free Flowing Traffic
5.1.3			Highway	High Speed(120kph)
5.1.4				High Speed(200kph)
5.2.1		Wet	Main Road	Traffic Jam
5.2.2				Free Flowing Traffic
5.2.3			Highway	High Speed(120kph)
5.2.4				High Speed(200kph)
6.1.1	Subject Vehicle Encounters Stopped Principle Other Vehicle	Dry	Main Road	Traffic Jam
6.1.2				Free Flowing Traffic
6.2.1		Wet		Traffic Jam
6.2.2				Free Flowing Traffic

Table 1: ACC Stop and Go Scenario Matrix

In general, all ACC scenarios could be summed up in one scenario; "SV (Subject Vehicle) encounters a slower POV (Principle Other Vehicle)." From this situation the SV, the car in back, will either coast or apply the brakes automatically till it is a certain pre-set distance from the car in front. Once the SV has reached this distance, the SV will then maintain the speed of the car in front. From this point the POV could accelerate, brake, or switch lanes and the SV will either accelerate or brake in all four of the scenarios (refer to figure 1).

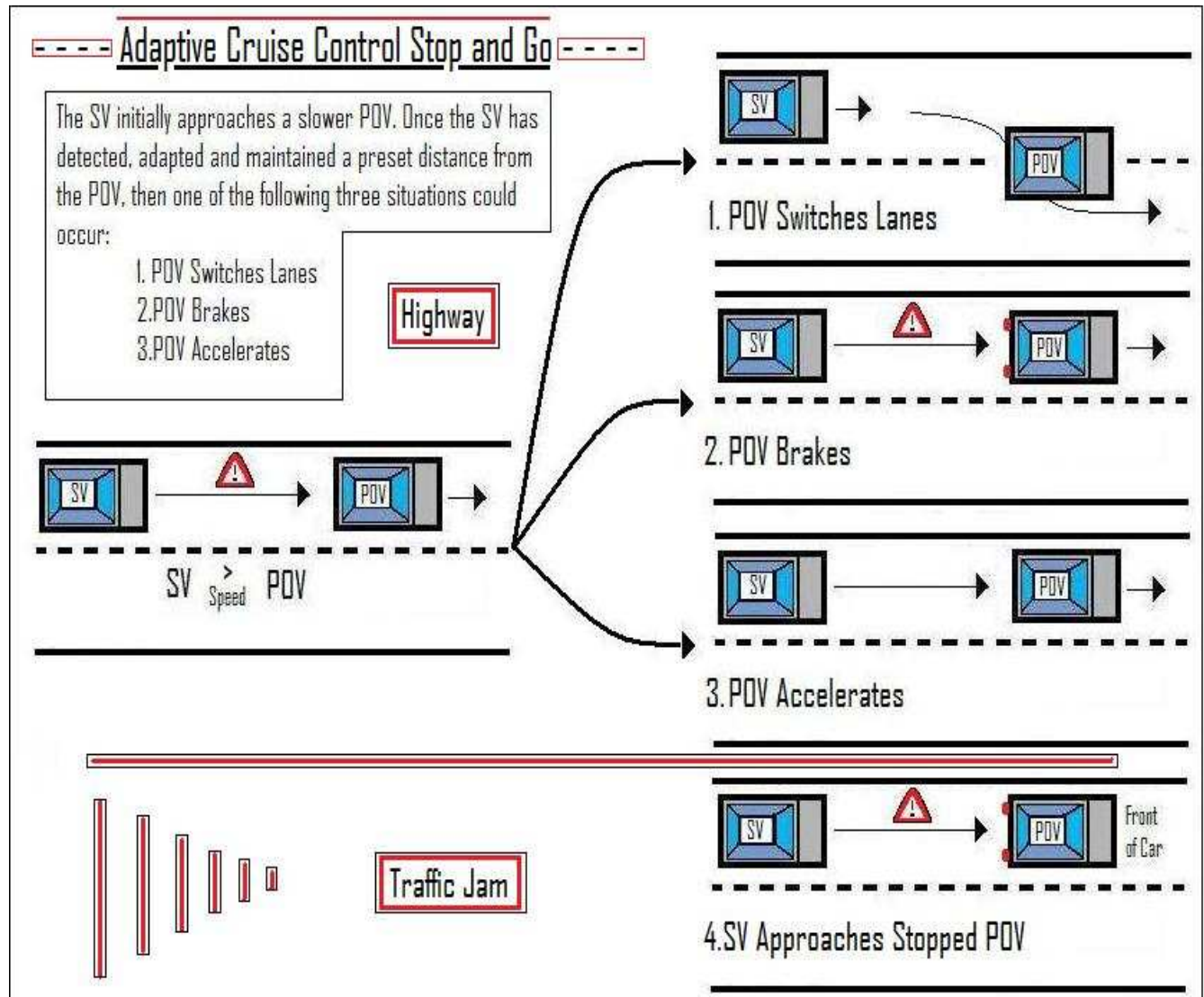


Figure 1: ACC Stop and Go

Now if the vehicles contains an ACC Stop and Go, then one more main scenario can be seen; "SV approaches a stopped POV." For this situation, the car will apply up to 25% of the braking capacity and if it is not enough a sound and display will alert the driver to take action to avoid a possible collision (refer to figure 1). [6] For further information on this testing protocol, refer to the ACC Stop and Go Testing Protocol document found in Appendix A.

3.2 FCW(Forward Collision Warning)

Another system of ADAS is FWC (Forward Warning Collision), which is similar to ACC, but differs in the fact that it is only for warning the driver in critical situations. This system uses information from a detection radar and calculates the TTC (Time-to-Collision) by finding the distance, azimuth, and relative speed between the vehicle with the FCW and the vehicle or object ahead of it. From here the system alerts the driver of the current situation and may have multiple warnings zones seen in figure 2. Also, these FCW systems cannot assist the driver with actions but only alert him or her in case of an emergency. [7] [8]

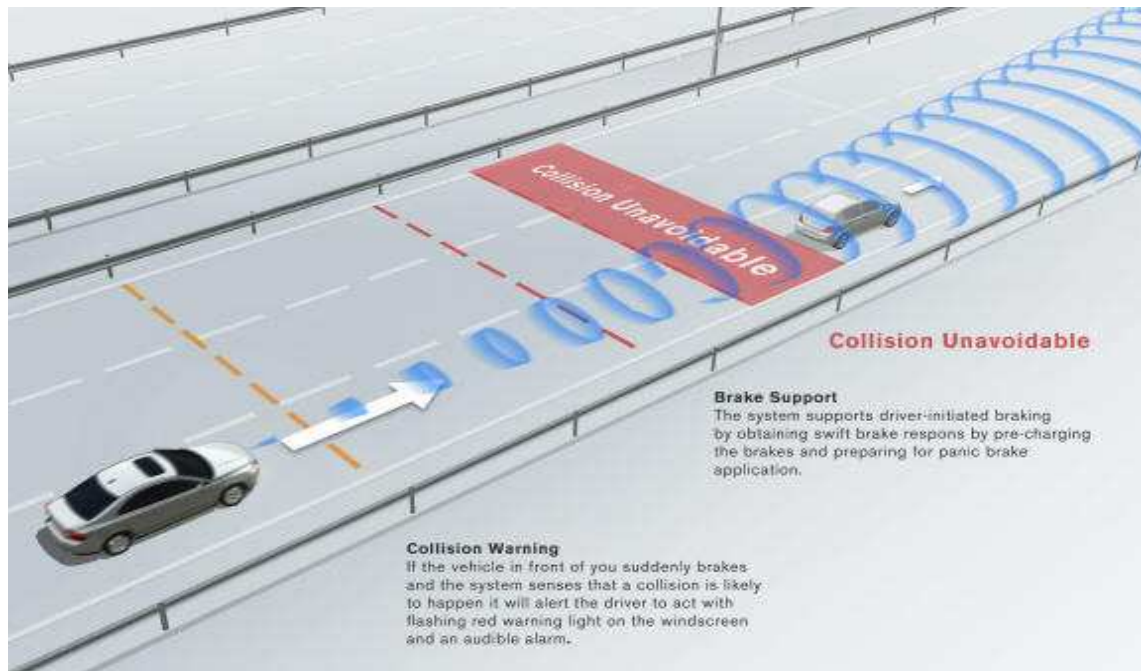


Figure 2: Forward Collision Warning

Currently, there is no standard testing method for FCW systems, due to the fact that they are so new. [7] Since this is the case, a protocol was developed that included three main scenarios, various decelerating percentages by the leading car, a few weather conditions including dry, wet and icy, along with different driving environments and speeds. The three scenarios that are tested in the FCW protocol are: "SV Approaching a Stopped POV", "SV Encounters Decelerating POV" and "SV Encounters Slower POV", which are three of the same tests in the ACC Stop and Go protocol. This is because FCW is used in the same environment, but FCW only does part of what the ACC systems can do. [8] For further information on this testing protocol, refer to the FCW Testing Protocol document found in Appendix B.

3.3 Pedestrian detection systems

Crashes where pedestrians are involved are fairly common, especially in urban areas. In order to avoid this kind of collisions there is a pedestrian detection system which works independently from respective walking styles or velocity of the pedestrian. Hence, the driver receives support in recognising people and performing a proper manoeuvre to avoid any collisions. All warm bodies, including humans, emit infrared radiation that can be detected with infrared imaging sensors. The example in figure 3 illustrates how the imaging sensors see the pedestrians.

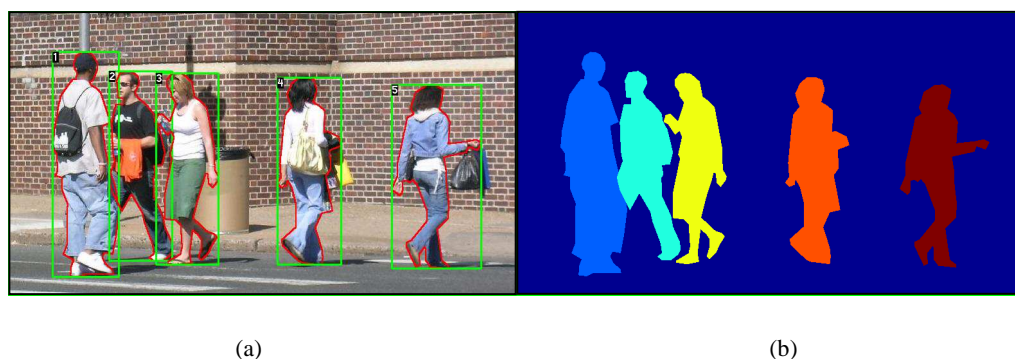


Figure 3: Picture (a) displays 5 pedestrians from the driver's point of view and picture (b) the same pedestrians from the cars point of view.

For a system to be able to detect a human, the facial temperature has to be significantly larger than the atmospheric temperature. When the atmospheric temperature is greater than 27°C the difference between the facial and the atmospheric is more than 5°C. The infrared imaging sensors can detect a human when the temperature difference is larger than 3°C.

Studies show that according to Planck's theory the facial temperature is almost constant when the atmospheric temperature is between 31°C and 36°C, which with the help of calculations leads to a maximum wavelength emitted by a human $\lambda \approx 9,5\mu\text{m}$. The results confirm the use of infrared sensors due to the fact that the appropriate wavelength for infrared detecting is between 8-13 μm . [9]

4. ITS (Intelligent Transport System) – state of the art

The ITS system exchanges information between OBU's and RSU's. During communication, either the OBU or the RSU can be the sender. The purpose of the ITS technology are mainly the increase of road safety as well as increasing the convenience of travel by car.

The most important function of ITS, is the exchange of road or traffic information. This data can be used to prevent crashes by providing the driver with the information of bad road conditions ahead or simply alert driver to decrease speed. Furthermore, it is possible for the data about the surrounding environment to hop from one car to the next as seen below in figure 4.

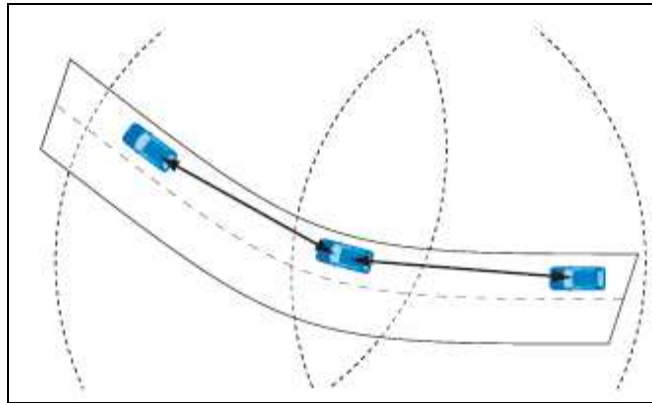


Figure 4: Vehicular communication on highway

Moreover, an intersection assistance can contribute to a significantly improved situation from a safety point of view in urban areas. Via Global Positioning System (GPS) the position, velocity and direction of vehicles can be detected and be compared to the data of cars in a close environment. This information will be sent to the driver in advance and will give him the possibility to adjust velocity in a way that avoids a collision. Due to this provision of information traffic lights get redundant and a steady drive is possible which affects the fuel consumption and safety in a positive manner. An intersection situation is being depicted in figure 5 below.

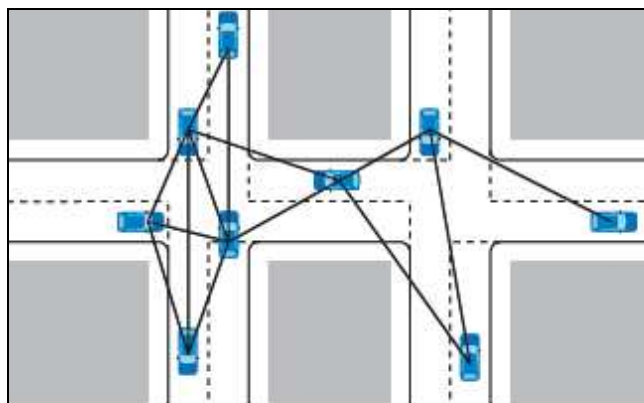


Figure 5: Vehicular communication at intersection

Another purpose is a wireless toll payment system, that enables road users to pay the toll while passing a RSU. The data will be submitted within a period of less than 100ms and therefore the need to stop in front of gates is unnecessary. The benefits of this purpose are avoided breaking and accelerating which consumes significantly more fuel than driving steadily.

Since the ITS is connected to the world wide web, movies can be downloaded to the intern vehicular entertainment system and can be played while traveling to keep passengers amused [10]-[12].

4.1 ITS Protocols

In order to exchange the respective data efficiently among the devices a data sending protocol is needed. This protocol manages the manner and order of sending data without any collisions with other messages. For example, a data package sent simultaneously with another will not reach the destination because the sending process will be abandoned due to interferences. The simple protocol would in this case try another submission after a random period of time. As it can be imagined this way of managing the data flow is not efficient enough to cope with multi message modes. Therefore, several amendments have been developed to equip the message to be sent with a message frame which includes a request for being allowed to send data and a following signal, indicating the sending process is finished. The mentioned technique, called Collision Avoidance, is a data sending process illustrated in figure 6. The data sending technology has to obey a certain standard. [11]

This standard, also known as WAVE (Wireless Access for the Vehicular Environment) is very useful in ITS communication system because it is based on a further special standard of ITS. The IEEE organization and a significant number of car manufacturers are striving to create a protocol that standardizes a communication network that allows information exchange between vehicles and road infrastructure. Initial tests showed that the 802.11 protocol is able to offer lower latencies than other IEEE communication protocols. [13]

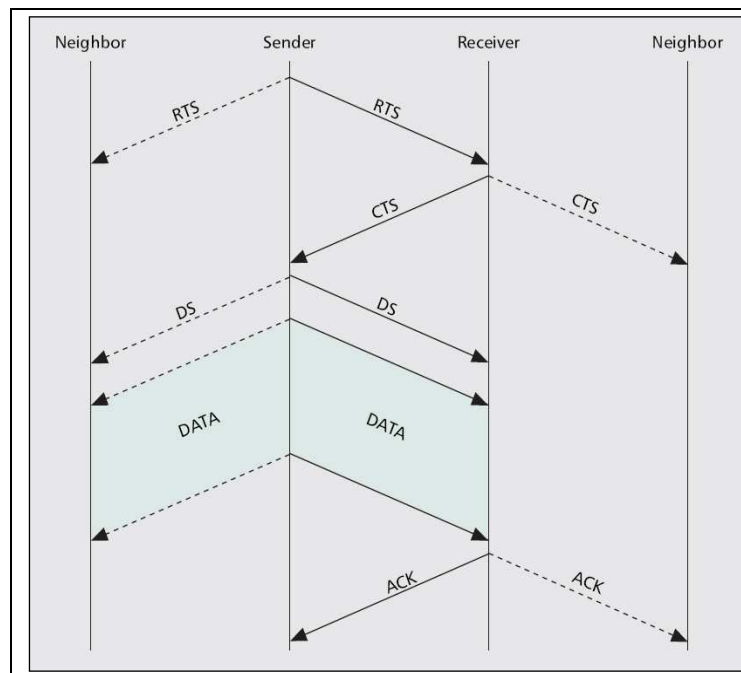


Figure 6: Advanced data sending process

The protocol named Multiple Access with Collision Avoidance (MACA) overcomes the interference problem by agreeing on transmission with the destination. The sender initiates this *handshake* by broadcasting a request to send (RTS) packet. So, all neighboring nodes inside this vehicular ad hoc network (VANET) are aware of the upcoming transmission. After receiving the RTS packet, the destination, if ready, replays by broadcasting a clear to send (CTS) packet, which informs all its neighbors about the upcoming transmission. By receiving the CTS packet, the sender can start the unicast transmission without any risk of collision, since its neighbors and those of the destination are aware about the ongoing transmission. Although, if a node receives the RTS but not the CTS, it can transmit, causing the exposed terminal problem. To let the exposed terminals be aware about the transmission duration time in its neighborhood, the protocol proposes to add data sending (DS) and acknowledgement (ACK) packets with regard to RTS and CTS packets. [11]

When compacting the several purposes mentioned in this report a difference in importance might become clear. In a situation where several messages needs to be send simultaneously, a queue will be crated in order to enqueue these messages and work down the list. In special situations there can be a queue with a random order related to the importance of those because the waiting list just considers the chronology. An announcement about a recently occurred emergency is for sure more urgent than a message about the latest version of a video to name an example. In this case it would be useful to change the order of the list depending on the most urgent message and send it as soon as possible in order to provide the road users with the latest and most relevant information. Therefore a scalability of data packages is necessary which requires a signature of any single message to figure out automatically which is the most urgent data to be send. Beside this signature the respective data package needs to get a rating of relevance and urgency to treat it in a proper way. To realize this technique is one of the current challenges to cope with. Figure 7 depicts a possible inquiring situation. [11]

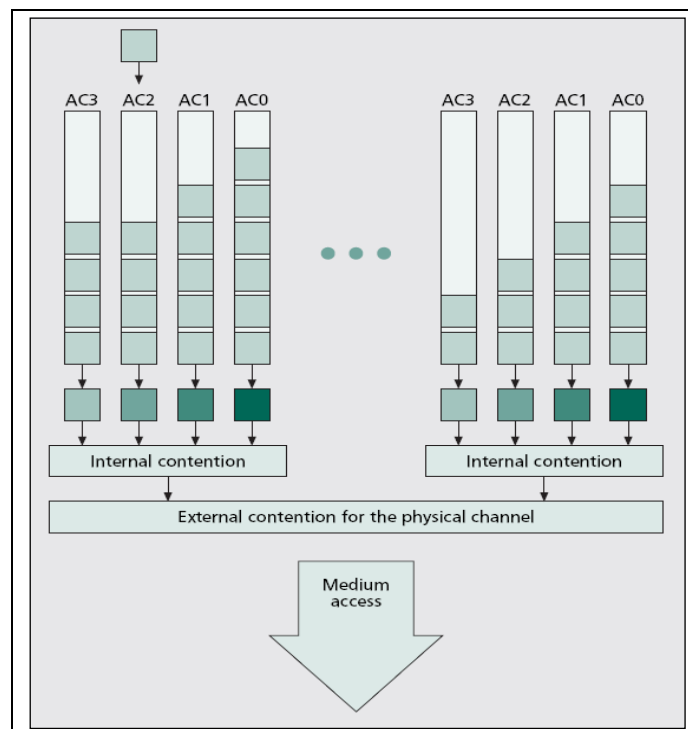


Figure 7: Internal and external message contention

4.2 ITS Projects

There are numerous public and private developments of ITS systems, but given the complexity and variety of disciplines and techniques involved, there is no single standardized project. In contrast, many countries have established their own agencies to promote the deployment of these systems. Appendix C states and describes a wide range of ITS projects.

4.3 Analysis on vehicle-to-infrastructure

In the upcoming years RSU's will be mounted along roads and most new car models will be equipped with OBU's, this to enable vehicle-to-infrastructure as well as vehicle-to vehicle communication.

Various applications within the Vehicle-to-vehicle and vehicle-to-Infrastructure field are considered for safety and commercial purposes, in appendix D this applications are listed. The main goal of the document in the Appendix D is to introduce communication requirements for a number of vehicle-to-infrastructure applications and, based on these, suggest a suitable technology.

5. HMI (Human Machine Interface) – state of the art

To enable the development of an evaluation protocol for HMI, a state of the art for the technology was created as a foundation for future work.

With drivers spending more and more time in their cars the need to improve the user friendliness of communication devices increases. Therefore, when designing new devices to submit important information to the driver, his behavior and perception should be considered to avoid causing confusion in situations which require high concentration.

Human Machine Interface (HMI) can be defined either in a physical or a procedure related way. The physical side describes the communication between the HMI devices and the user, whereas the procedure means the necessary interactions to perform the dialogue. The interactions in table 2 describe the basics of HMI.

Type of Interaction	Procedure of Dialogue	Role of the driver	Examples	Physical Means
Information	Dialogue about the status of the vehicle-traffic system or about a service the driver is asking for	Taking decision about the impact of the information on his / her task and possibly perform an action	Medium range pre-information, RDS-TMC Travel information	Visual, audio
Warning	Signalling a situation of potential danger or deviation from the intended goal (typically if the driver does not take actions)	Taking decision about the action to be taken and possibly performing it	Collision warning Driver status monitoring	Visual, auditory
Advice	Indications about actions to be performed to accomplish a stated goal	Following the advice and take actions or deciding to override it	Route guidance	Display, audio
Control	Parts of the driving task are taken over by the system	Supervising and possibly overriding the system	Adaptive cruise control	

Table 2: HMI Description

5.1 HMI Devices Using In Vehicles

In today's vehicles, there are many different HMI devices being used. This chapter of the report describes some of the most common devices.

5.1.1 Speech recognition

Speech recognition enables converting spoken words to machine-readable input. It can be divided into *isolated word recognition* and *continuous speech recognition*.

When commands are very long or have many similar words, recognition becomes more difficult. *Finite-state network* is the simplest network to identify the words and sentences clearly. The

other problem in speech recognition is perplexity and it is related to combine the size and complexity of words and the respective language and its pronunciation. The problem is defined as phonetic variability occurring due to acoustic differences of the phenomenon.

Speech does not require training and is much faster than any other way of input. Moreover, this system is relatively cheaper than other input systems because complex devices are not required.

Speech Recognition can be applied for actions like Voice Dialing, Call Routing, Domestic Application Control and content-based spoken audio search, simple data entry and speech-to-text processing. [14]

5.1.2 TFT LCD Displays

TFT (Thin Film Transistor) LCD (Liquid Crystal Display) improve the image quality compared to usual LCDs. Thin Film Transistor consists of FPDs (flat-panel displays) and should be light, ergonomic and have a high screen resolution as well as a low power consumption.

LCD screens are one of the most popular examples of TFT Displays. Applications includes: television sets, computer monitors, mobile phones and computers, handheld video game systems, personal digital assistants, navigation systems, projectors, etc.

Active Matrix Liquid Crystal Displays (AMLCDs), figure 8, are opposed to passive matrix and dual scan displays and are furthermore leading the flat-panel display technology. In general a display consists of a grid defining as a picture of elements. There are millions of these pixels on one single image. The quality of AMLCDs is mainly related to the quality of the glass used to build the display. Hence, the glass should have an excellent optical clarity and include the standard semiconductor process. However glass is very fragile and therefore, scientists have developed a special plastic with the same clarity like glass. Other benefits of this material are that it is more flexible and lighter than before. For high tech applications silicon based TFTs are preferred because of low leakage currents and low threshold voltages. [15]

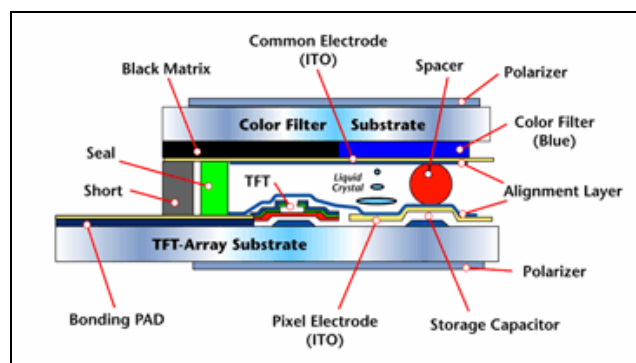


Figure 8: The combination of different colored pixels forms the image on the panel

5.1.3 HUD (head up display)

HUD is a type of transparent display, seen in figure 9, that beams data to be shown on a certain surface like glass. The main advantage of this technology is that information can be displayed to the driver on a transparent material. This enables the driver to receive and read the information without being distracted. [16]



Figure 9: Example of HUD application in a car

When designing HUD systems, following factors need to be considered:

- Field of vision
- Eyebow - displays
- Luminance/contrast – displays
- Display accuracy - aircraft HUD
- Installation - installation of HUD

5.1.4 Touch screen

Touch screens are widely used in mobile phones, ATM machines, HMI devices, medical monitors, industrial control panels, transportation systems and more. The benefits of touch screen are the improved operability because displayed elements can be selected by pushing with the finger on the display; every kind of buttons is therefore redundant. Moreover Touch Screens are not only helpful of output operations but also for input activities like writing. This can be done right on the screen. Touch screens can be categorized as Active Digitizer and Passive Touch Screen. [17]

5.2 Subjective HMI protocol

In today's society, user comfort and user-machine friendliness is becoming an increasingly important component when designing devices for vehicles. Therefore this part of the project focuses on drivers' behaviors.

5.2.1 HMI Questionnaire

The questionnaire was made for getting drivers' opinions about devices which are used directly in a car by the driver. To read the questionnaire see Appendix E. Because of IDIADA's request for creating a HMI Guideline and evaluation protocol, the most important thing is to learn about drivers' behaviors and opinions. To realize this aim, a questionnaire including seven basic questions, was made. In order to collect representative data, participants where supposed to give detailed answers. Probands were from a comprehensive range related to age and nationality. After collecting the data a thorough analysis was made to derive the guideline from the results.

5.2.2 HMI Guideline

The HMI guideline considers the devices which drivers are used to apply. After deciding that these devices can be Navigation devices, CD-DVD-Radio players, road computer, main indicators and air condition system, HMI guideline was prepared with utilizing of drivers' opinion. The complete guideline document is to find in Appendix F.

The document in the appendix contains the features of the devices mentioned which provide a more comfortable, safer and more user-friendly driving than without the devices. So the designers are the target audience of the guidelines which is designed entirely driver-focused. [18]-[21]

5.2.3 Evaluation Protocol

In the last task an evaluation protocol was created, which can be found in Appendix G. This protocol serves as a tool for testing the devices mentioned in the HMI Guideline. In order to achieve the best evaluation the mentioned questionnaire and guideline was used to create detailed and purposeful questions.

Separate protocols were created for each instrument mentioned in the guideline. To receive better testing results, the possible answers were divided into five categories. On the one hand, by making basic comments about the answers and simply calculating the arithmetic average of the total test points, the evaluation protocol stays clear and does not become too complex. On the other hand, the use of target-oriented, meaningful questions ensures the quality of the testing results. With this protocol the evaluator can get a general idea of the respective device. According to the point system which has a range from one to five, devices with a score of three points or more are suitable to be used in a car. [22]

6. Scenario research

After a thorough research on the topics of ITS and ADAS, studies of accident statistics and insurance companies were performed. With the information gained a base for brainstorming scenarios where ITS and ADAS can be used to prevent and decrease the consequences of an accident as well as to increase the comfort for the driver was created.

In order to obtain accurate results it is important to distinguish between ITS and ADAS. ITS systems are designed to prevent accidents well in advance by communication between OBU's and RSU's. Whereas, the aim of ADAS systems is to alert and assist the driver when an accident is close. The actions can include automatic braking and steering of the car.

There are an infinite number of possible scenarios where accidents can occur in a traffic situation. Therefore, the scenarios have been grouped into two major headings with subheadings. The main headings for the scenarios are *Common Traffic environments* and *Special circumstances*.

6.1 Common traffic environments

Traffic environments are either static constructions such as intersections or roundabouts, or common situations like overtaking another car and the shifting of lanes.

6.1.1 Intersections and roundabouts

When approaching an intersection the driver should be not only aware of the vehicles driving in the same direction and vehicles traveling in the opposite direction but also intersecting vehicles. In figure 10 a large intersection with traffic flowing in all directions is displayed. The more lanes interfering at one intersection the greater is the risk for collision between cars. Even though infrastructure security includes stop-signs, stop-lights and other warning signals there are many accidents per year in intersections mostly due to driver's errors. [23]



Figure 10: Intersection with a total of 12 lanes intersecting each other

ITS systems are helpful when driving towards a major intersection giving the driver important information about the upcoming situation well in advance. The information can be received either with V2V communication or through V2I communication. Important to note is that information can only be given or received by a car with ITS installed. With V2I a driver that has bought a ITS device can receive information about the upcoming intersection even though cars in the surrounded area are lacking the equipment. This is possible due to that the system is using cameras to gain information about the accurate traffic situation. [23]

When in the intersection, ADAS systems can assist the driver when an unexpected situation appears. The assistance can involve alerting the driver about the upcoming circumstances or acting for the driver with breaking or steering.

A roundabout, one is pictured in figure 11, is a traffic situation very similar to intersections. The difference is the possibility lane changing within a roundabout. Wherefore, the ADAS system, *lane changing assistance*, can be of good help as well as the lane-keeping assistance to help the driver keeping his or her lane while driving in a circular path.



Figure 11: Roundabout with four different roads intersecting

6.1.2 Shifting lanes

When driving, there are many situations where it is necessary to shift lane from one to another. The reason can for example be either be to overtake another vehicle or that the current lane is not suitable for the desired route.

There is a high risk involved in shifting lanes. Especially when overtaking of another car involves shifting into a lane with the oncoming traffic. This situation is described in figure 12 where car 1 is overtaking car 2. Car 1 and 2 are in a cooperative group together with car 3 which indicates that there is information flowing between the three cars through ITS communication. Due to the use of the communication technology an accident with car 4 can be avoided because of that car 3 detects the oncoming car and sends the information to the rest of the members in the cooperative group. The example of the cooperative group also displays the use of a combination between ADAS and ITS.

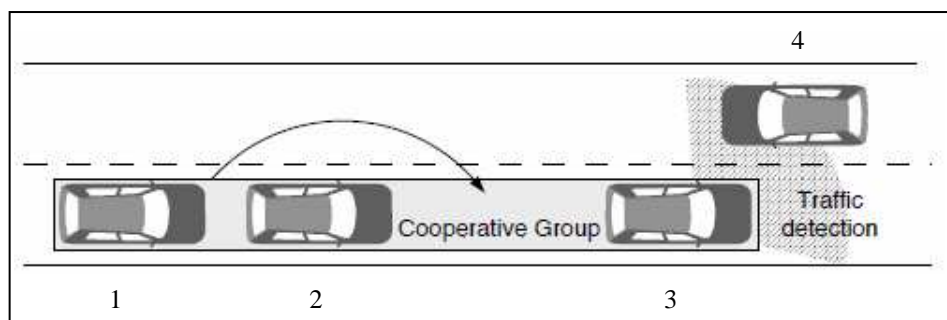


Figure 12: Cooperative grouping an overtaking situation

The ACC system for lane changing is a type of ADAS. Sensors detect cars in blind spots with either radar or cameras. The entity can alert the driver with signals or assist with the steering and/ breaking in dangerous situations. An example of a lane changing assistance system from Volkswagen is displayed in figure 13.

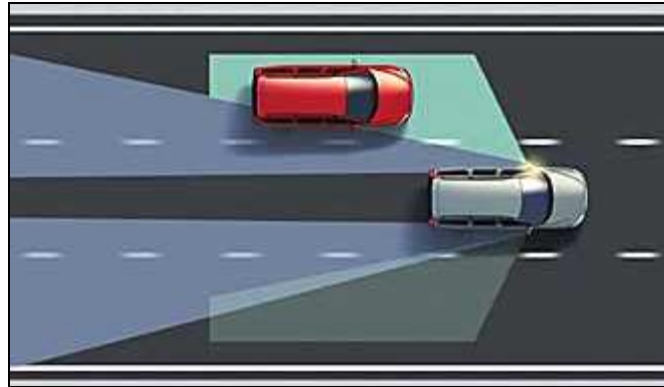


Figure 13: Lane changing system from Volkswagen

6.1.3 Hills and corners

When approaching hills and corners, the sight can be a restricted. Figure 14 displays a hill on a two lane road. Drivers have to be extremely careful especially when they want to increase the speed or overtake another car. In these cases, ACC radar equipment is not suitable due to the fact that the car is not travelling in a straight path and the radar can have problems to detect the right vehicles. The most suitable system in these cases could be either ITS Car-to-Car or ITS car-to-infrastructure communication.



Figure 14: Hill in a traffic situation

6.2 Special circumstances

There are some situations where accidents are more likely to occur. One example of a situation like this would be a street next to a school where risk of a child running across the road is high. The high risk situations are collected in the group of special circumstances.

6.2.1 Urban areas

Driving in a highly populated urban area demands extra concentration. The following list contains some of the major urban scenarios:

- Highly-density traffic roads
- Pedestrians crossing the road when not allowed and when not supposed to, an example is illustrated in figure 15.
- High concentration of one-way streets
- High risk of unexpected events: kids, animals etc.



Figure 15: Urban pedestrian situation

ITS systems such as V2V and V2I are not suitable for inner city traffic, this due to the amount of unpredictable situations that can occur. Therefore, the communication technology recommended in urban areas is ADAS because of its possibilities to detect cars, obstacles and pedestrians as well as act in assistance for the driver.

6.2.2 Decreased visual conditions

When driving in bad visual conditions, safety transport systems can be a vital help as a geographical guide. ACC technologies can assist in choosing the most appropriate driving speed according to weather and road conditions. There are also other systems within the ADAS family that can be useful, for example pedestrian detection system can alert the driver about a for the driver non-visual persons. If the driver does not react according to the warning signal from the ADAS system the device can assist with the emergency breaking.

Communication between OBU's and RSU's can give the driver information about the visual condition further down on the current road. Received data could include the status of the street lightning or the degree of a rainfall.

6.2.3 Road works

Every year road workers die because of non aware drivers. The number of accidents has been increasing over the past years [24]. Therefore, new technologies could increase the safety for the construction workers on the road side; a worker close to the traffic is displayed in figure 16.



Figure 16: Road worker very close to heavy traffic

If a roadside unit gets informed about a nearby roadwork it could send this signal to the surrounding cars and the next RSU which would pass the signal forward.

6.2.4 Traffic jams

One of the major purposes with the ITS technology is to prevent traffic jams through information sharing between cars and infrastructure. If there is a large traffic jam on the road the driver shall be noticed and recommended another route. This has many positive consequences such as decreased amount of hours driving and more constant driving behaviour which decreases the fuel consumption. The mentioned consequences also lead to decreased cost per kilometre for the car owner and a decreased concentration of CO₂ in the affected area.

7. IDIADA's proving ground

To be able to implement the test scenarios on IDIADA's proving ground a study of the test tracks and lab equipment was performed. This chapter describes the most relevant parts of IDIADA's assets.

7.1 Testing tracks

IDIADA's proving ground, which is illustrated in figure 17, includes 12 different testing tracks. The tracks are the following:

1. A 7560 m high speed circuit; the turns have a 472m radius to enable tests at maximum speeds.
2. External noise track with two different surfaces for tests of noise emitted from a vehicle.
3. Fatigue track with six different surfaces for long distance testing
4. Dynamic platform A, with extreme smooth asphalt and 0% gradient
5. Dry handling track
6. Five test hills, gradients from 8 to 30 degrees.
7. Wet breaking surfaces
8. Specific Comfort surfaces
9. Dynamic platform B, with extreme smooth asphalt and 0% gradient
10. Off road track including for example a mud area and a sand track for testing of 4WD (four wheel drives)
11. Wet circle
12. Wet handling track [25]

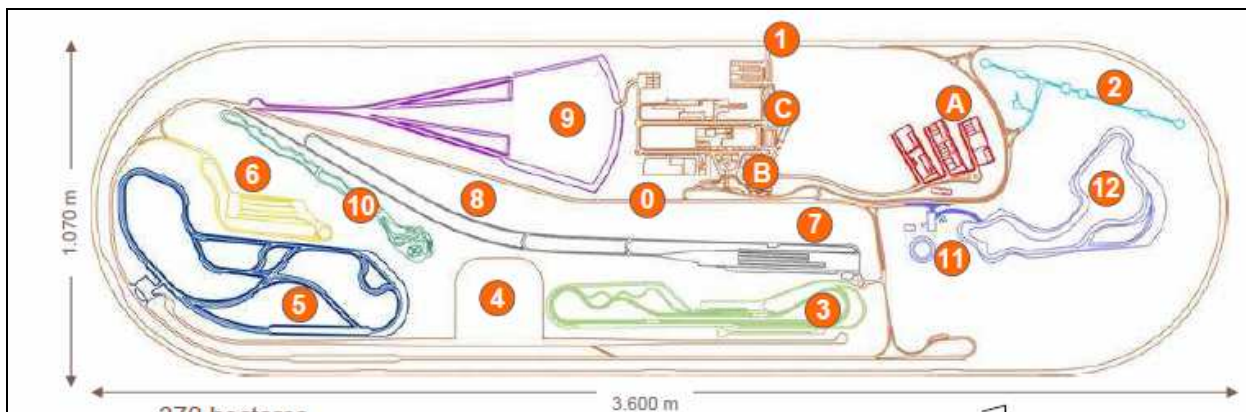


Figure 17: IDIADA's proving ground

Furthermore, there are roads connecting the tracks. These roads are equipped with roundabouts and intersections and can also be used for testing purposes. The whole area has a very high level of security that enables car companies to test their upcoming models at IDIADA without fear of news leaking out.

7.2 Lab equipment

IDIADA is providing tests of ADAS devices. The tests are performed with the help of advanced lab equipment and simple car profiles. Pictured in figure 18 is a test of an ACC system. A car is approaching an intersection where a red car dummy is passing and the ACC device is to detect the passing vehicle.



Figure 18: Car profile for tests in intersections

The scenario from figure 18 is also illustrated in figure 19 where it is possible to see that the red car profile is attached on a real car that is reversing into the intersection.

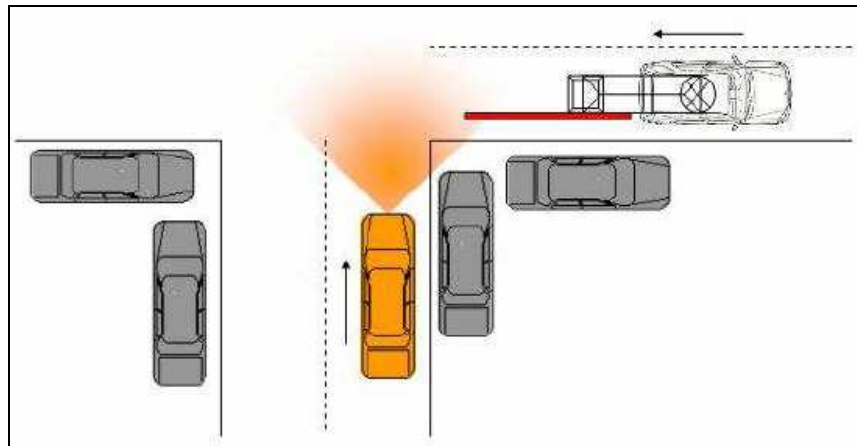


Figure 19: Intersection testing scenario

Another car profile for tests in intersections is displayed in figure 20. This profile is connected to a cable in which allows the profile to pass across the street. In comparison to the profile displayed in figure 18 and 19, the profile is not restricted by the length of the mounted profile.



Figure 20: Car profile for testing in intersection

When performing tests for lane changing assistance a scenario can proceed as seen in figure 21. The car that is being passed is equipped with a protecting shield in case of the tested system does not work in the appropriate way.

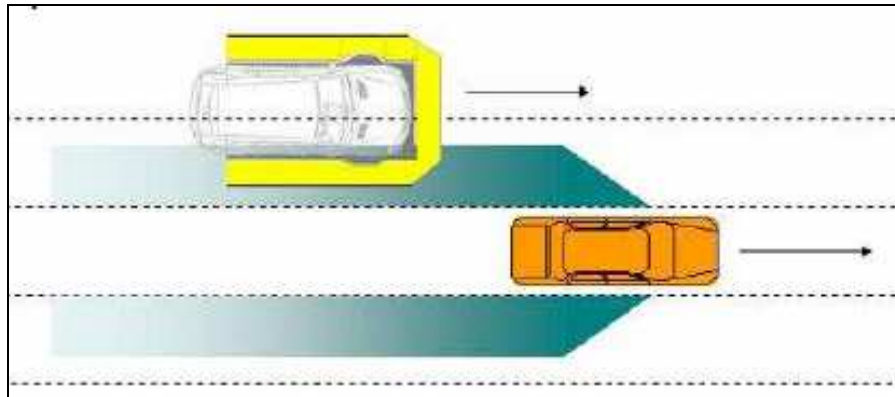


Figure 21: Test of lane changing assistance

Illustrated in figure 22 is the car used for the test described in figure 21. The protecting shield is removable to enable the car to be used for other types of tests as well.



Figure 22: Car with protecting shield

IDIADA keeps a high level of security in the tests they are providing. Therefore, they offer the possibility of unmanned cars driving and breaking with the help of technical equipment. A steering robot is illustrated in figure 23.



23: Figure a steering robot

Figure 24 illustrates a breaking robot for which the braking pressure easily can be measured.



Figure 24: Breaking robot

8. Testing scenarios

After analysis of IDIADA's proving ground as well as research on different possible scenarios where ITS and ADAS can be helpful for a driver, testing scenarios for ITS were developed. The complete description of all scenarios including illustrations and informative texts is to read in Appendix H.

In chapter five of this report, eight different traffic scenarios were described. Out of these one, urban areas, was decided as an area where ITS devices are not suitable for assisting the driver. In an urban area unexpected circumstances are common and high concentration level is needed from the driver. Therefore the reason for not using ITS, is that ITS demands actions of the driver whereas some ADAS systems can act for the driver which is more suitable when the time is very limited.

The different tests are described in Appendix H. The tests are illustrated with the help of Illustrator CS4 as well as with pictures from IDIADA's proving ground. In figure 25 two vehicles equipped with ITS devices are approaching an intersection. The picture is an example of one out of three different testing scenarios for V2V. The aim of the intersecting testing scenarios is to analyze when the driver receives the information about the other car and if the information is sufficient and accurate.

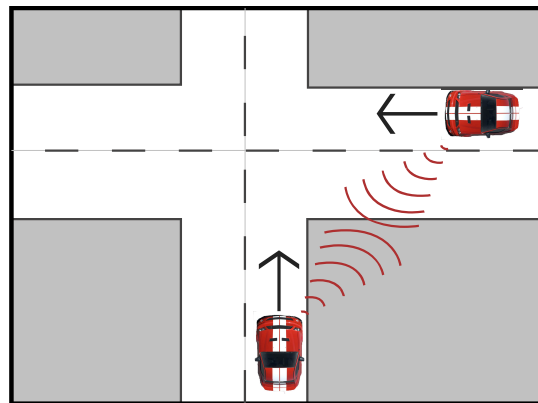


Figure 25: Testing scenario including two cars in an intersection

Another example of one of the testing scenarios is displayed in figure 26. A car is approaching a hill where on the other side there is a car that has broken down and is now blocking the way. Only the driving car is equipped with an OBU (Onboard Unit). But the camera on the RSU detects the first car and through communication between two RSU and then to the OBU in the vehicle the driver of the second car becomes aware of the situation ahead.

The hill scenario is to be tested on all five testing hills on IDIADA's proving ground to analyze if the results differ when the gradient of the hill increases.

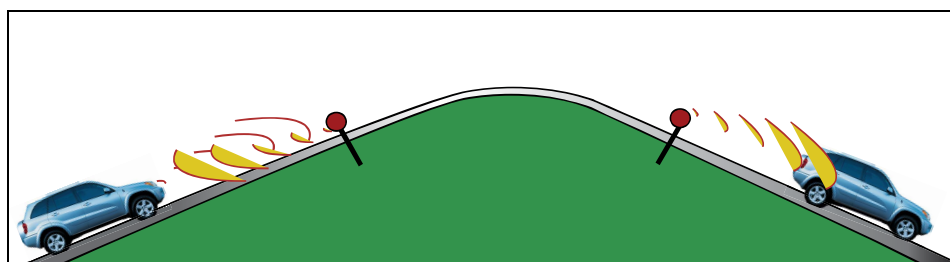


Figure 26: Testing scenario including two cars in a hill

The developed testing scenarios give IDIADA a possibility to see what type of tests they can performed with existing equipment and what type of tools they need to purchase or develop to make all tests possible.

9. Possible applications

When working with driver information systems the possible applications of those are of strong interest. It needs to be answered where these systems can be applied, what can be accomplished with it and how the current and future technology can be utilised best. Even though ITS enables a wide range of possibilities, the focus of this research is on the over all goal to increase the safety of vulnerable road users and improve efficiency aspects.

One goal from both a safety and efficiency point of view is to realise a fluent traffic flow, especially in urban regions. Therefore, avoiding redundant breaking and acceleration manoeuvres would be beneficiary. The approach here is to implement a traffic light support which recommends the optimal speed to have a steady traffic flow. The system is capable of taking both traffic lights and detection of other cars into consideration to recommend a relative velocity in order to reduce the chances of a collision. Figure 27 depicts several communicating cars at an intersection.

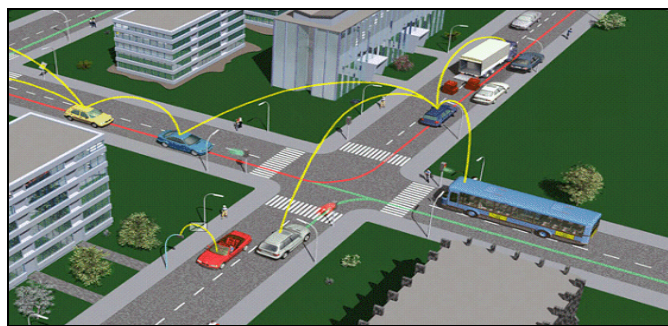


Figure 27: ITS communication at an intersection

A wireless toll payment system would also consider the aspect of avoiding traffic stumbles by abolishing the need to stop in front of gates to pay the toll.

Both given examples concentrate on a car to infrastructure communication between OBUs and RSUs. Another safety enhancing application of ITS is the exchange of relevant road condition information which would be helpful in extreme weather situations or when a crash already occurred. A situation where data is being exchanged is illustrated in Figure 28.

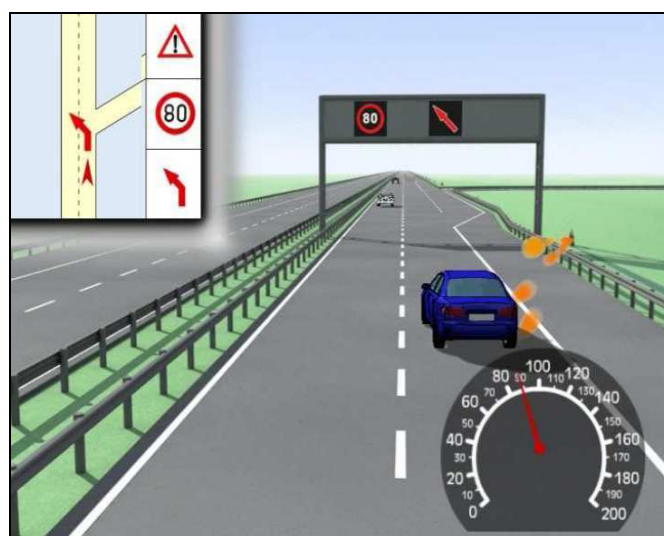


Figure 28: Communication between an OBU and a RSU

10. ITS/ADAS data base

In order to gain an overview of ITS and ADAS regulations a data base was created with the most important ISO standards and worldwide regulations related to these systems. This data base should be designed as support for IDIADA's employees for developing new testing methods and services for driver systems. Another advantage of the database is a good overview of all ADAS models which are available on the market. Thus, this data base needs to be designed as user friendly as possible, which can be achieved by dividing the data into several chapters. Therefore, the data base is created with Microsoft Excel and separated into four main parts to provide information about ISO standards for ADAS and ITS with short descriptions of the standards, worldwide standards which are used by European ADAS projects and a collection about ADAS devices on the market. In figure 29 one section of the base can be seen.

ISO number	Technology/System	Standard title	Status	Link for more information	Last updated
ISO 15622:2002	ACC	Transport information and control systems -- Adaptive Cruise Control Systems -- Performance requirements and test procedures	Published	AttachmentISO 15622.doc	Jul 07
ISO 15623:2002	ACC	Transport information and control systems -- Forward vehicle collision warning systems -- Performance requirements and test procedures	Published	AttachmentISO 15623.doc	Mar 08
ISO 22838	ACC	Vehicle roadway warning and control) Enhanced ACC	Published		May 06
ISO/PRF 22173	Full Speed Range ACC	Intelligent transport systems -- Full speed range adaptive cruise control (FSRA) systems -- Performance requirements and test procedures	Under development		Dec 08
ISO 16950:2007	Pedestrian recognition	Road vehicles -- Pedestrian protection -- Child head impact test method	Published	AttachmentISO 16950.doc	Jun 07
ISO 17386:2004	Lidar	Transport information and control systems -- Manoeuvring Aids for Low Speed Operation (MALSO) -- Performance requirements and test procedures	Published	AttachmentISO 17386.doc	Apr 08
ISO/AVI 28902	Lidar	Ground-based remote sensing of visual range by lidar	Under development		Nov 06
ISO 13695:2004	Lidar (Laser)	Optics and photonics -- Lasers and laser-related equipment -- Test methods for the spectral characteristics of lasers	Published	AttachmentISO 13695.doc	Sep 07
ISO 13697:2006	Lidar (Laser)	Optics and photonics -- Lasers and laser-related equipment -- Test methods for specular reflectance and regular transmittance of optical laser components	Published	AttachmentISO 13697.doc	Jan 09
ISO 11145:2006	Lidar (Laser)	Optics and photonics -- Lasers and laser-related equipment -- Vocabulary and symbols	Published	AttachmentISO 11145.doc	Jan 09
ISO 15367-1:2003	Lidar (pulsed Laser)	Lasers and laser-related equipment -- Test methods for determination of the shape of a laser beam wavefront -- Part 1: Terminology and fundamental aspect	Published	AttachmentISO 15367.doc	Dec 08
ISO 11953-1:2005	Lidar (Laser)	Safety of machinery -- Laser processing machines -- Part 1: General safety requirements	Published	AttachmentISO 11953.doc	Sep 08
ISO 11670:2003	Lidar (Laser position)	Lasers and laser-related equipment -- Test methods for laser beam parameters -- Beam positional stability	Published	AttachmentISO 11670.doc	Dec 08
ISO 11951:2003	Lidar (Laser)	Optics and optical instruments -- Lasers and laser-related equipment -- Test method for absorbance of optical laser components	Published	AttachmentISO 11951.doc	Dec 08
ISO/TR 22588:2005	Lidar (Laser)	Optics and photonics -- Lasers and laser-related equipment -- Measurement and evaluation of absorption-induced effects in laser optical components	Published	AttachmentISO_TR 22588.doc	Sep 05
ISO 11951-1:2000	Lidar	Lasers and laser-related equipment -- Standard optical components -- Part 1: Components for the UV, visible and near-infrared spectral ranges	Published		Jul 05
ISO 18434-1:2008	Infrared Camera	Condition monitoring and diagnostics of machines -- Thermography -- Part 1: General procedures	Published	AttachmentISO 18434.doc	Feb 08
ISO/TR 11146-3:2004	CCD	Lasers and laser-related equipment -- Test methods for laser beam widths, divergence angles and beam propagation ratios -- Part 3: Intrinsic and geometrical laser beam classification, propagation and details of test methods	Published	AttachmentISO_TR 11146-3.doc	Dec 07
ISO 22952	Radar	(Wide area communication) Medium and long range (wireless) Communications Requirements	Published		May 06
ISO 17287:2003	ADAS design	Road vehicles -- Ergonomic aspects of transport information and control systems -- Procedure for assessing suitability for use while driving	Published	AttachmentISO 17287.doc	Sep 08
ISO 16673:2007	ADAS design	Road vehicles -- Ergonomic aspects of transport information and control systems -- Occlusion method to assess visual demand due to the use of in-vehicle	Published	AttachmentISO 16673.doc	Mar 07
ISO 17287:2003	ADAS design	Road vehicles -- Ergonomic aspects of transport information and control systems -- Procedure for assessing suitability for use while driving	Published	AttachmentISO 17287.doc	Sep 08
ISO/TC225/SC 13	ADAS design	Ergonomics as Applicable to Road Vehicles	Published	AttachmentISO_TC 22_SC 13.doc	Sep 01

Figure 29: ISO data base example

As a first step for creating this data base a document about the international main standards was created. This document gives an overview about how the IT architecture of an ITS system should look like and depicts different approaches to a comprehensive solution.

The standards related to ITS integrated into the data base define the general way of information exchange between OBUs and RSUs and specify further on the format of this message exchange for general ITS applications. The needed protocols and parameters for long range and medium speed communication in the sector of ITS is also provided by the considered standards, as well as the communication tool for DSRC applications. As for these applications a high transmission rate up to 1 Mbit/s and a high speed medium access is necessary the respective requirements are specified in ISO 11898-2:2003 and ISO 11898-5:2007 [26].

For ADAS the collection of all technology devices of different manufactures helped to compare the technical data and to identify first similar technical standards. To make the search of standards for employees easier, the ADAS ISO norms are divided into different technologies (radar, lidar, camera and infrared) or systems (ACC, ACC Stop & Go or Pedestrian recognition systems). Besides, there exist general ISO standards about ADAS technology which are differentiated by the European Commission into three main components. These components are procedural ISO's for the fundamental architecture and vocabulary, ISO's for design like

ergonomic aspects and norms about visual information and presentation of man machine interfaces, named performance. [27] The ISO webpage provides a lot of standards that are related to road transport, in-vehicle-systems and vehicle communication but the framework of the European Commission sets its priorities on the ACC system which is the reason why most of the found standards are based on ACC technology. [26] For evaluating and testing ADAS systems also worldwide standards and regulations like safety regulations for in-vehicle electronic are important. With the aid of existing European ADAS projects, like the DRIVE project for road and transport traffic telematic, it was possible to identify the most practical and used regulations which are available in the part *Worldwide Standards* of the base. For more information about the data base see the digital document called Data Base ADAS_ITS.

11. ITS and ADAS service business

Since IDIADA is a service provider, the current requirements in this market needed to be considered. The tertiary sector has been developed into the most important field of the international economy over the last decade in relation to the gross domestic product. [28] [29] The reasons for this development are various. Most important are the changes due to the internationalisation which basically means that there are no spot related advantages anymore. Information and products can be sent in a short period of time around the world supported by the internet and international trade related laws.

These circumstances require flexibility of companies and cause the intention of outsourcing in order to be able to focus on the core competences of the firm. Therefore, IDIADA can be successful as a service business company in the field of automotive engineering. For this portion of the project, the task was to write a service offer for IDIADA's clients, advertising the test services IDIADA offers in the field of ADAS and ITS.

11.1 Target group

Important when addressing information of any kind to a customer is to know which level of knowledge the company has. In case of IDIADA the customers are organisations which mean IDIADA is operating in a business to business (B2B) way. Hard to define was the profession of the representatives and if there might be a buying center for the procurement of service businesses at the clients company. Finally, none of these cases could be confirmed by IDIADA so that a very broad target group with basic knowledge in the field of ADAS and ITS was assumed. This target group does not have special information but is informed roughly about the functions of the systems. Moreover, the potential client can be either an already socialised customer who has been made business with IDIADA yet, or a new customer which would require an acquisition function from the documents. [30]

11.2 Context

Since IDIADA is an actor in a B2B branch it is obvious that every single contact to clients is personally. Hence, the elaboration to be created would be a tool for direct marketing and is when issued always based on a conversation in advance. In order to work as close as possible to the praxis, the decision was to write a handbook and a presentation for each: ADAS and ITS.

11.3 Handbook

The intention of the handbooks was to write a document which states the special features of the systems, explains these features roughly and advertises possibilities to test them. These handbooks can be used for several purposes. When having a meeting it can for example be issued to business partners in order to give a first impression about the new services. Moreover, this document can be sent to potential clients or even be published on IDIADA's homepage if this matches their strategies. The handbooks consider the corporate identity of IDIADA regarding applied colors and logos and are supposed to suggest two independent possibilities of creating such advertisements. Therefore, and because the purpose of the documents is not utterly clear, the layouts are not consistent and are supposed to get amended for a special application. The handbook for ITS and ADAS can be found in Appendix I and Appendix J.

11.4 Presentation

As mentioned before, also two presentations were elaborated for both: ADAS and ITS. According to the assumption, that IDIADA's representatives will have the chance to present the new test services personally to the potential clients it seemed to be a practical idea to prepare this situation with a comprehensive presentation created with Microsoft Power Point. This presentation contains, similar to the handbook, the features of the assistant systems and IDIADA's concept for analysing and testing them. The goal of this presentation is to introduce the newly available services and to give the audience a professional overview about the characteristics of both systems. As well as the handbook the layout of the presentations is not consistent because the idea was to suggest two different ways of realising this challenge. Also in this portion of the task, the corporate identity of IDIADA was taken into account to make it easy for the audience to identify the company in the future. The presentations for ITS and ADAS can be seen in Appendix K and Appendix L.

12. Conclusion

As this report states out the project was directed towards different goals, which are correlated to each other and can be connected roughly.

This report introduces the most important ADAS functions, for which a protocol was developed, and states the benefits of these systems. Also applications, the state-of-the-art and necessary communications protocols for ITS are discussed in order to know how to use limited mediums efficiently. The driver information systems ADAS and ITS provide lots of information. Thus, this elaboration also reports about the work done in the field of HMI, where data was collected from a poll and analysed to derive a guideline from it. Since IDIADA has a very sophisticated proving ground the project work included to develop scenarios where ADAS and ITS can be implemented. The so researched scenarios were matched with the possibilities on the proving ground. Another portion of this report renders the work done about standards. The most important international ones were collected in a data base which gives a clear overview for IDIADA's stuff. Finally, the researched facts in this report need to be advertised to IDIADA's clients. Therefore, a comprehensive service offer was created in form of a handbook and a presentation.

The project work benefited from web based information about recently performed projects as well as branch related articles and magazines.

13. Recommendations

Future work in the topic of ADAS and ITS can be specified for the respective subchapters. The HMI portion can be improved due to more intensive observations of probands. Therefore, more participants from different nationalities and age need to be interviewed. Moreover, an observation in a simulator could help to collect representative data in various scenarios which would be beneficiary for designers and engineers of future devices.

This data can also be used to improve the practical test scenarios on the proving ground in order to perform more realistic examinations with both: hardware and software. Also necessary for this purpose is the design and procurement of special devices for ADAS and ITS tests. The installation of RSU's to the proving ground would be beneficiary.

When improving the ADAS protocols it is inevitable to perform tests with every kind of vehicle which shall be equipped with ADAS in the future. These vehicles like buses or motorcycles etc. should also be used for tests in various conditions like fog, smoke, hail and a wide range of temperatures to ensure faultless functionality. Further on, a test run with several systems performing parallel would also help to gain additional experience.

If these test methods are being improved, also the service business part of the project can be specified. Further on, the target group of IDIADA should be defined in detail to set up a consistent marketing concept for ADAS and ITS test services.

14. Bibliography

- [1] European Union. Summary of Legislation. Inc Retrieved May, 14, 2009, <http://europa.eu/scadplus/leg/en/lvb/l24257.htm>
- [2] Study results. Feasibility Study for the Setting – up of a Performance testing programme for ICT- based Safety Systems for Road Transport, 20 September 2007.
- [3] Neuendorf, N. ESG. (2006). An autonomous intersection management free of traffic lights components of success and development. PowerPoint Presentation. An International Automotive Electronics Congress, Paris, France.
- [4] Minister, C. (2006). TRW Autocruise. PowerPoint Presentation. International Automotive Electronics Congress, Paris, France.
- [5] Edgar, Julian. Technology of Active Cruise Control. Auto Speed. Issue 420: 28 February, 2007. 11 May, 2009, http://autospeed.com/cms/title_Technology-of-Adaptive-Cruise-Control/A_108268/article.html
- [6] Audi. Adaptive Cruise Control. Inc. Retrieved June 11, 2009, http://www.audi.co.uk/audi/uk/en2/new_cars/a8_new/a8_new/electronics/adaptive_cruise_control.html
- [7] US Department of Transportation, Federal Motor Carrier Safety Administration. Forward Collision Warning System (CSW(. Inc. Retrieved May 31, 2009, <http://www.fmcsa.dot.gov/facts-research/research technology/report/forward collision warning-systems.htm>
- [8] US Department of Transportation, National Highway Traffic Safety Administration. (2008). Forward Collision Warning System Confirmation Test. Washington, DC: Office of Vehicle Safety, Office of Crash Avoidance Standards.
- [9] Hirota, M., & Co. Human body detection technology by thermoelectric infrared imaging sensors. Nissan Motor Co, LTD Japan.
- [10] Penn Engineering. (2009). Inc. Retrieved June 09, 2009, http://www.cis.upenn.edu/~jshi/ped_html
- [11] Adler C., Eichler S., & Co. (2006). The Scalability Problem of Vehicular Ad-Hoc Networks and How to Solve it.
- [12] Menouar H., Fiali, T., & Hitachi M. (2006). A Survey and Quantitative Analysis of MAC Protocols for Vehicular Ad-Hoc Networks.
- [13] Chen W., & Shengwei C. (2005). Ad-Hoc peer to peer network architecture for vehicle safety communications.
- [14] Deegener, M., & Kellum C. (2007). An Analysis of the Differences between the Evolving United States and European Dedicated Short Range Communications (DSRC) Systems.
- [15] Wayne A. L. (1980). Trends in Speech Recognition. Prentice Hall New Electronic on Campus.
- [16] College of engineering UC Berkley, Inc. Retrieved May 10, 2009, www.eecs.berkeley.edu

- [17] WiseGeek. Online Lexicon. Clear answers for common questions. Technology and Gadgets. Inc. Retrieved May 10, 2009, www.wisegEEK.com
- [18] Pc Magazine. The independent Guide to Technology. (2009). Inc. Retrieved May 10, 2009, pcmag.com
- [19] Audioholics- Online A/V Magazine. Pursuing the Truth in Audio and Video. Inc. Retrieved June 10, 2009, <http://www.audioholics.com/buying-guides/how-to-shop/dvd-cd-players-buying-guide>
- [20] Hammer, M., Douglas F.-C., & Tobin, D. (2007). Technology and driver distraction—the need for industry guidelines. In: I.J. Faulks, M. Regan, M. Stevenson, J. Brown, A. Porter & J.D. Irwin (Eds.). Distracted driving. Sydney, NSW: Australasian College of Road Safety.
- [21] Turkish Sharing Platform. DVD/CD Radio Players. Inc. Retrieved June 10, 2009, <http://www.baktabulum.com/motorlu-araclar-ve-modifiye/26235-iyi-bir-oto-muzik-sistemi-icin-nelere-dikkat-edilmeli.html>
- [22] Turkish Sharing Platform. Trip Road Computer. Inc Retrieved June 10, 2009, <http://www.hackhell.com/motorlu-araclar-amp-modifiye-dunyasi/89106-yol-bilgisayari.html>
- [23] CitySync. Intelligent Transport Systems, Inc. Retrieved June 11, 2009, http://www.citysync.co.uk/go.php/en/sectors/its_-_intelligent_transport.html
- [24] Liljegren, E. (2008-2009). Research Report. Trafik olyckor vid vägarbeten 2003-2007, published by Vägverket.
- [25] Applus IDIADA. Proving Ground. PDF Document, provided by Raul Carrasco.
- [26] International Organization for Standardisation. Inc. Retrieved May 10, 2009, <http://www.iso.org/iso/home.htm>
- [27] European Commission. Legislation and standardisation; telematics networks. Inc. Retrieved May 10, 2009, http://www.etsi.org/Website/document/aboutETSI/EC_Mandates/M270.pdf
- [28] Meffert, H., Bruhn, M. (2006). Dienstleistungsmarketing. Grundlagen – Konzepte – Methoden, 6th ed. Wiesbaden.
- [29] Homburg, C., Krohmer, H. (2006). Marketingmanagement - Strategie – Instrumente – Umsetzung – Unternehmensführung, 2nd ed. Wiesbaden, Germany: Betriebswirtschaftlicher Verlag Dr. Th. Gabler/ GWV Fachverlage GmbH.
- [30] Top Business AG. Systematical Customer Acquire, Inc. Retrieved June 06, 2009, <http://www.topbusinessag.com/deutsch/top-hr-training-consulting-seminare-beratung/training-beratungsseminare/einkauf-undvertrieb/vertrieb/einneukd.html>

15. References

- Adler C., Eichler S., & Co. (2006). The Scalability Problem of Vehicular Ad-Hoc Networks and How to Solve it.
- Audi. Adaptive Cruise Control. Inc. Retrieved June 11, 2009, http://www.audi.co.uk/audi/uk/en2/new_cars/a8_new/a8_new/electronics/adaptive_cruise_control.html
- Audioholics- Online A/V Magazine. Pursuing the Truth in Audio and Video. Inc. Retrieved June 10, 2009, <http://www.audioholics.com/buying-guides/how-to-shop/dvd-cd-players-buying-guide>
- Applus IDIADA. Proving Ground. PDF Document, provided by Raul Carrasco.
- Chen W., & Shengwei, C. (2005). Ad-Hoc peer to peer network architecture for vehicle safety communications.
- CitySync. Intelligent Transport Systems, Inc. Retrieved June 11, 2009, http://www.citysync.co.uk/go.php/en/sectors/its_-_intelligent_transport.html
- College of engineering UC Berkeley, Inc. Retrieved May 10, 2009, www.eecs.berkeley.edu
- Deegener, M., & Kellum C. (2007). An Analysis of the Differences between the Evolving United States and European Dedicated Short Range Communications (DSRC) Systems.
- Edgar, Julian. Technology of Active Cruise Control. Auto Speed. Issue 420: 28 February, 2007. 11 May, 2009, http://autospeed.com/cms/title_Technology-of-Adaptive-Cruise-Control/A_108268/article.html
- European Commission. Legislation and standardization. Telematics networks. Inc. Retrieved May 10, 2009, http://www.etsi.org/Website/document/aboutETSI/EC_Mandates/M270.pdf
- European Union. Summary of Legislation. Inc Retrieved May, 14, 2009, <http://europa.eu/scadplus/leg/en/lvb/l24257.htm>
- Hammer, M., Douglas F.-C., & Tobin, D. (2007). Technology and driver distraction—the need for industry guidelines. In: I.J. Faulks, M. Regan, M. Stevenson, J. Brown, A. Porter & J.D. Irwin (Eds.). Distracted driving. Sydney, NSW: Australasian College of Road Safety.
- Hirota, M., & Co. Human body detection technology by thermoelectric infrared imaging sensors. Nissan Motor Co, LTD Japan.
- Homburg, C., Krohmer, H. (2006). Marketingmanagement - Strategie – Instrumente – Umsetzung – Unternehmensführung, 2nd ed. Wiesbaden, Germany: Betriebswirtschaftlicher Verlag Dr. Th. Gabler/ GWV Fachverlage GmbH.
- International Organisation for Standardization. Inc. Retrieved May 10, 2009, <http://www.iso.org/iso/home.htm>
- Liljegren, E. (2008-2009). Research Report. Trafik olyckor vid vägarbeten 2003-2007, published by Vägverket.
- Meffert, H., Bruhn, M. (2006): Dienstleistungsmarketing. Grundlagen - Konzepte – Methoden, 6nd ed. Wiesbaden.

- Menouar H., Fiali, T., & Hitachi M. (2006). A Survey and Quantitative Analysis of MAC Protocols for Vehicular Ad-Hoc Networks.
- Minister, C. (2006). TRW Autocruise. PowerPoint Presentation. International Automotive Electronics Congress, Paris, France.
- Neuendorf, N. (2006). ESG. An autonomous intersection management free of traffic lights components of success and development. PowerPoint Presentation. An International Automotive Electronics Congress, Paris, France.
- Pc Magazine. The independent Guide to Technology. (2009). Inc. Retrieved May 10, 2009, pcmag.com
- Study results. Feasibility Study for the Setting – up of a Performance testing programme for ICT- based Safety Systems for Road Transport, 20 September 2007.
- Top Business AG. Systematcal Customer Acquise, Inc. Retrieved June 06, 2009, <http://www.topbusinessag.com/deutsch/top-hr-training-consulting-seminare-beratung/training-beratungsseminare/einkauf-undvertrieb/vertrieb/einneukd.html>
- Turkish Sharing Platform. DVD/CD Radio Players. Inc. Retrieved June 10, 2009, <http://www.baktabulum.com/motorlu-araclar-ve-modifiye/26235-iyi-bir-oto-muzik-sistemi-icin-nelere-dikkat-edilmeli.html>
- Turkish Sharing Platform. Trip Road Computer. Inc Retrieved June 10, 2009, <http://www.hackhell.com/motorlu-araclar-amp-modifiye-dunyasi/89106-yol-bilgisayari.html>
- US Department of Transportation, Federal Motor Carrier Safety Administration. Forward Collision Warning System (CSW(. Inc. Retrieved May 31, 2009, <http://www.fmcsa.dot.gov/facts-research/research-technology/report/forward-collision-warning-systems.htm>
- US Department of Transportation, National Highway Traffic Safety Administration. (2008). Forward Collision Warning System Confirmation Test. Washington, DC: Office of Vehicle Safety, Office of Crash Avoidance Standards.
- Wayne A. L. (1980). Trends in Speech Recognition. Prentice Hall New Electronic on Campus.
- WiseGeek. Online Lexicon. Clear answers for common questions. Technology and Gadgets. Inc. Retrieved May 10, 2009, www.wisegeek.com